

Locomotor Dysfunction after Spaceflight: Characterization and Countermeasure Development

Mulavara AP^{1*}, Cohen HS², Peters BT³, Miller CA³, Brady R³, Bloomberg JJ⁴

¹Universities Space Research Association, Houston, TX 77058, TX 77058, ²Bobby R. Alford Department of Otorhinolaryngology and Communicative Sciences, Baylor College of Medicine, Houston, TX 77030, ³Wyle Life Sciences, Houston, TX 77058, ⁴Neuroscience Laboratories, NASA-Johnson Space Center, Houston

^{1*}ajitkumar.mulavara-1@nasa.gov; Ph: 2814838994; Fax: 2812445734

Astronauts returning from space flight show disturbances in locomotor control manifested by changes in various sub-systems including head-trunk coordination, dynamic visual acuity, lower limb muscle activation patterning and kinematics (Glasauer, et al., 1995; Bloomberg, et al., 1997; McDonald, et al., 1996; 1997; Layne, et al., 1997; 1998, 2001, 2004; Newman, et al., 1997; Bloomberg and Mulavara, 2003). These post flight changes in locomotor performance, due to neural adaptation to the microgravity conditions of space flight, affect the ability of crewmembers especially after a long duration mission to egress their vehicle and perform extravehicular activities soon after landing on Earth or following a landing on the surface of the Moon or Mars. At present, no operational training intervention is available pre- or in- flight to mitigate post flight locomotor disturbances.

Our laboratory is currently developing a gait adaptability training program that is designed to facilitate recovery of locomotor function following a return to a gravitational environment. The training program exploits the ability of the sensorimotor system to generalize from exposure to multiple adaptive challenges during training so that the gait control system essentially “learns to learn” and therefore can reorganize more rapidly when faced with a novel adaptive challenge. Ultimately, the functional goal of an adaptive generalization countermeasure is not necessarily to immediately return movement patterns back to “normal”. Rather the training regimen should facilitate the reorganization of available sensorimotor sub-systems to achieve safe and effective locomotion as soon as possible after space flight. We have previously confirmed that subjects participating in adaptive generalization training programs, using a variety of visuomotor distortions and different motor tasks from throwing to negotiating an obstacle course as the dependent measure, can learn to enhance their ability to adapt to a novel sensorimotor environment (Roller et al., 2001; Cohen et al. 2005). Importantly, this increased adaptability is retained even one month after completion of the training period. Our laboratory is currently developing adaptive generalization training procedures and the associated flight hardware to implement such a training program, using variations of visual flow, subject loading, and treadmill speed; during regular in-flight treadmill operations.

As part of the effort to evaluate this training regimen, we have collected pre and post flight locomotion data from International Space Station Expeditions 5-12 (n =18) who will serve as a control group. One test we have used to evaluate astronaut post flight locomotion is the Functional Mobility Test (FMT). The FMT required subjects to step over and duck under foam obstacles along with walking through a series of pylons set up on a 6.0 m X 4.0 m obstacle course set up on a base of 10 cm thick medium density foam. Subjects were instructed to walk through the course as fast but as safely as possible without touching any of the objects on the course. This task was repeated three times each in the clockwise and the counterclockwise directions. The time to complete the course (TCC) data from all 18 subjects for each post flight day were averaged and collated for further analysis. A logarithmic curve using a least squares procedure was fit through these points and its intersection with the average \pm 95% confidence interval of the mean preflight TCC across all subjects was calculated to determine the duration of time taken to recover functional locomotor performance. Results from FMT of the 18 subjects indicate that the adaptation to space flight led to a significant increase in time to traverse the obstacle course and recovery of function took an average of 2 weeks after their return. Understanding the modes of post flight re-adaptation has implications for development of in-flight training regimens.

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